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*ASP Conference Series, Vol. **VOLUME**, **PUBLICATION YEAR***

****EDITORS****

Tracing cosmic evolution with the Coma cluster

Bianca M. Poggianti

Osservatorio Astronomico, vicolo dell'Osservatorio 5, 35122 Padova -I

Terry J. Bridges

*Anglo-Australian Observatory, PO Box 296, Epping, NSW 1710,
Australia*

Bahram Mobasher

*Space Telescope Science Institute, 3700 San Martin Drive, Baltimore,
MD 21218, USA*

Dave Carter

*Liverpool John Moores University, Twelve Quays House, Egerton Wharf,
Birkenhead, Wirral, CH41 1LD, UK*

Abstract. We summarize here the first results of a new spectroscopic survey of galaxies in the Coma cluster with $-20.5 < M_B < -14$. Differences between the last epoch of star formation (SF) activity in S0 and elliptical galaxies are discussed. Furthermore, we show that about half of all galaxies without present-day SF display signs of activity at $z < 1 - 2$. Systematic trends of most recent SF epoch with galaxy luminosity are presented.

1. Introduction

In this contribution we report on the first results of a new spectroscopic survey of galaxies in the Coma cluster. This survey was designed to have three main characteristics:

- 1) It extends over almost 7 mag in galaxy luminosity ($-20.5 < M_B < -14$), well into the dwarf regime. In fact, this is by far the largest spectroscopic sample of cluster dwarf galaxies to date.
- 2) It covers two areas of $33' \times 50'$ (1×1.5 Mpc) towards the center and the southwest region of Coma. The photometry (B and R) has been obtained with the Japanese Mosaic CCD camera at the William Herschel Telescope (WHT) in collaboration with M. Doi, M., Iye, N. Kashikawa, Y. Komiyama, S. Okamura, M. Sekiguchi, K., Shimasaku, M. Yagi, N. Yasuda.
- 3) It is essentially a magnitude limited sample, without significant color or morphological bias, therefore it includes galaxies of all Hubble types.

We obtained multifiber spectra with the WYFFOS fibre spectrograph at the WHT for about 300 galaxies members of Coma and 200 field galaxies. The spectra cover the central 2.2 arcsec (1.3 kpc) of the galaxies and have a mean S/N

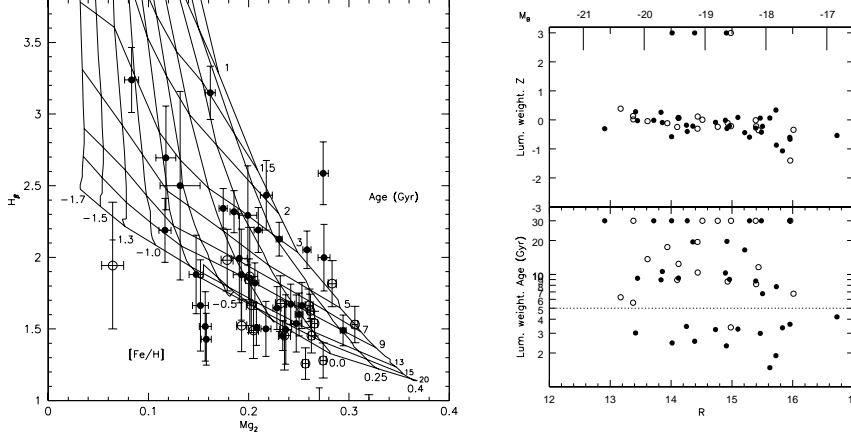


Figure 1. *Left.* $H\beta$ versus Mg_2 index strength for ellipticals (empty circles) and S0 galaxies (filled circles). *Right.* Luminosity weighted metallicities (top) and ages (bottom) of ellipticals (empty circles) and S0 galaxies (filled circles) as a function of the R-band magnitude.

ranging from 16 for the brightest subset to 8 for the faintest subset. Hence, the errorbars on the spectral line measurements are large for the faint galaxies, and for them only broad conclusions regarding ages and metallicities can be reached. *Here we consider only the ~ 250 galaxies without emission lines in their spectra.* For them, we have measured the absorption line indices in the Lick system. The stellar properties (luminosity weighted ages and metallicities) have been derived from index-index diagrams, comparing with spectrophotometric models based on the Padova isochrones (http://astro.sau.edu/~worthey/dial/dial_a_pad.html, Worthey). A full description of the results presented here can be found in Papers III and IV. The dataset is described in Papers I and II.

2. S0 versus elliptical galaxies

There are 19 ellipticals and 33 S0s in our sample with a secure morphological classification from Dressler (1980). All but one of the ellipticals are consistent with luminosity weighted ages ≥ 9 Gyr, while 13 S0s have ages < 5 Gyr (Fig. 1, left). Thus, a significant fraction ($> 40\%$) of the S0s show evidence for some recent SF. This is consistent with the hypothesis that they evolved from star-forming spirals that were accreted onto the cluster and had their SF truncated at intermediate redshifts (Dressler et al. 1997, Fasano et al. 2000, see also van Dokkum and Treu in these proceedings). This difference in age spread between Es and S0s is similar to the results of Kuntschner & Davies (1998) in the Fornax cluster and Smail et al. (2001) in A2218. In contrast, other works (e.g. Jones, Smail & Couch 2000, Ellis et al. 1997) have not found a statistically significant difference between the ages of the stars in S0s and Es. It is obviously important to understand whether S0s with recent SF are a *common* phenomenon in clusters or not. In this respect, it is interesting to look at the age distributions

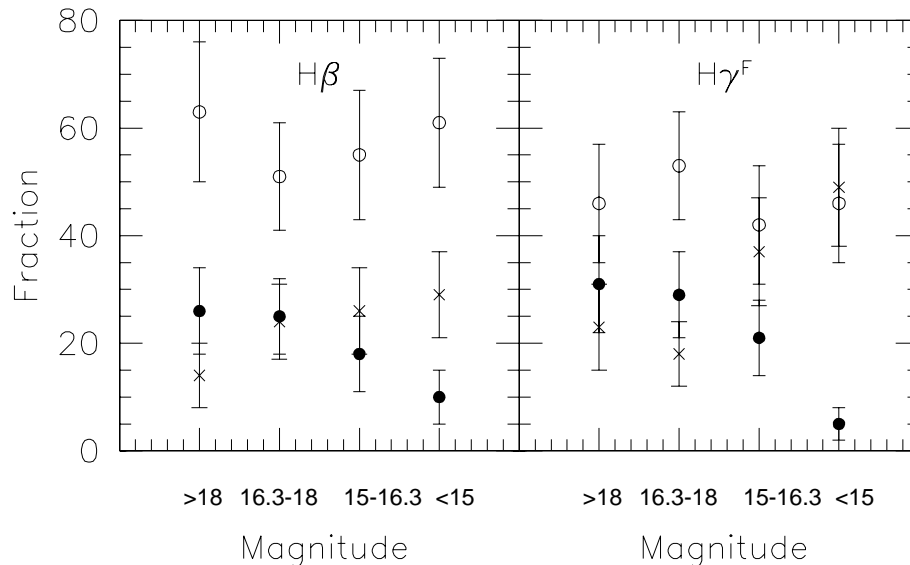


Figure 2. Fraction of young (filled dots, age < 3 Gyr), intermediate-age (crosses, 3 to 9 Gyr) and old (empty dots, age > 9 Gyr) galaxies within each magnitude bin as derived from the $H\beta/Mg_2$ diagram (left) and the $H\gamma_F/\langle Fe \rangle$ diagram (right).

of galaxies as a function of magnitude.¹ In Fig. 1 (right), the population of S0s with recent SF is noticeable below the dotted line: only 4 of the “young” S0s are brighter than $M_B = -19$. In fact, considering galaxies brighter and fainter than $M_B = -19$, bright and faint Es have similar age distributions, while the fraction of S0s with recent SF is higher at fainter luminosities. Therefore, a possible reason for the discrepant results found so far (recent SF in cluster S0s, yes or no) could be the luminosity range explored by the different studies. Given the luminosity function of spirals at $z \sim 0.5$ and the expected fading if their SF

¹We note that S0s and Es follow a broadly similar metallicity-luminosity relation (top in the right panel of Fig. 1), although the relation for the S0s is slightly steeper and more scattered than that of the Es.

is halted, the great majority of the spirals evolved into S0s should be typically fainter than $M_B = -20/-19$.²

3. The infall history of the Coma cluster

In the following we will consider the complete spectroscopic sample with no emission lines, including galaxies of all magnitudes and Hubble types. This sample represents the total cluster population of galaxies without current SF. There is a broad range of ages, from younger than 3 Gyr to older than 9 Gyr, among galaxies of any magnitude. However, there are systematic trends of age with galaxy magnitude. Dividing all galaxies into four magnitude bins, $\sim 50\%$ of galaxies in any bin are “old”, i.e. with no sign of SF during the last 9 Gyr (at $z < 1-2$). As shown in Fig. 2, the proportion of *luminous* galaxies that are passive at $z=0$ and that experienced a SF activity at intermediate redshift ($0.35 < z < 1$) is 30 to 50 %, and it is higher than the fraction of *dwarf* galaxies that were active at that epoch. This is consistent with the observations of current/recent SF in a large number of galaxies in intermediate- z clusters (e.g. Dressler et al. 1999). At low redshift, instead, SF involved a higher fraction of faint than bright galaxies. These results can be used to trace the infall history of galaxies onto Coma, and the consequent star formation history of its present-day galaxies. The luminosity(mass) dependence of the most recent SF epoch points to a “down-sizing effect”, and can be compared with the accretion history of clusters predicted by cosmological models.

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²Those S0s with recent SF have an asymmetric distribution in the sky, being preferentially located in a region east/north-east of NGC4874 (the cluster centre), while older S0s and ellipticals are spread out both north and south of NGC4874.